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CORRELATION OF SHAPE AND STATION IN FRESH-WATER MUSSELS (NAIADES).

By A. E. ORTMANN, Ph.D.

(*Read April 24, 1920.*)

While studying the Naiad-shells of the upper Ohio-drainage, the fact was forced upon my mind, that certain species which inhabit the headwaters and smaller streams are represented, in the larger streams, by different, but very similar forms, which are distinguished from them chiefly by one character, namely obesity. The headwaters-forms are rather compressed or flat, the large-river-forms more convex and swollen. I also found that in the rivers of medium size integrades betwen the extremes were actually present.

Subsequently, similar conditions appeared to prevail elsewhere, and the existence of this rule was brought home to me very forcibly during my study of the Naiad-fauna of the upper Tennessee drainage.

Also other authors have observed this fact, and have referred to it in their publications. Thus Wilson and Clark[1] indicated it for certain species of the Cumberland River (*Amblema peruviana* and *costata; Rotundaria tuberculata* and *granifera; Dromus dromas* and *caperatus*) and Utterback[2] has found this law to hold good in Missouri (chiefly in the Osage River) for several species (*Fusconaia undata* and *trigona; Amblema peruviana* and *costata; Pleurobema obliquum* and allied forms).

I myself have alluded to this relation between a compressed headwaters-form and a swollen large-river-form in the case of *Obovaria lens* and *subrotunda*,[3] in the case of *Pleurobema coccineum*

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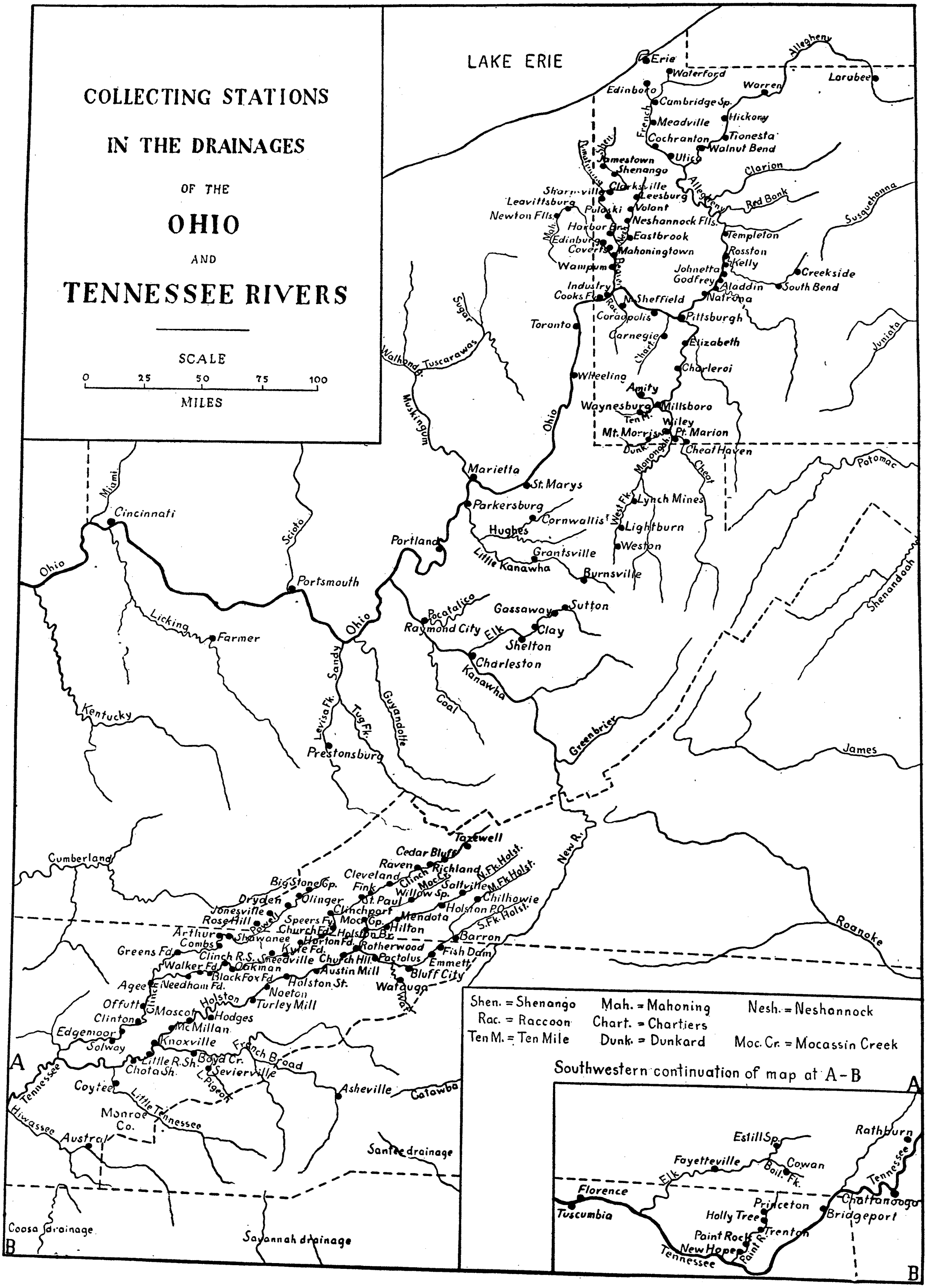
[1] Bur. Fisher. Doc. no. 781, 1914, pp. 21 and 63.

[2] *Amer. Midl. Natural.*, 4, 1916, p. 2.

[3] *Ann. Carn. Mus.*, 5, 1909, p. 192.



COLLECTING STATIONS IN THE DRAINAGES OF THE OHIO AND TENNESSEE RIVERS

and *obliquum*[4] and in the case of the group of *Fusconaia barnesiana.*[5] I have given a fuller account, including the synonymy of the forms concerned. Additional references may be found in my paper on the upper Tennessee shells[6] and on the Pennsylvanian Naiades.[7]

However, all this information is rather vague, and not supported by detailed measurements, and, before we finally assume that this law exists at all, we should substantiate it by more careful investigations. The present paper is written with the purpose to supply the details and to reduce them to figures.

When we speak of the *obesity* of mussel shells, and call them *flat* and *compressed,* or *convex* and *swollen,* we refer to the proportional *diameter* of the shell. This diameter can be expressed in various ways, but I found that the most easy is in percentage of the length. The length is always measured parallel to the lingament,[8] which can be done, without difficulty, by placing the shell between the arms of a vernier caliper measure in the proper position. The diameter is measured at right angles to it, and always the maximum diameter of the two valves is taken, no matter where it is located. The length is then taken as = 100, and the diameter expressed in hundredths of the length.

The material studied has been collected, for the largest part, by myself, and thus I am able to vouch for the correctness of the localities. It forms part of the collections of the Carnegie Museum in Pittsburgh. Yet there is additional material from other sources. The Carnegie Museum possesses a fine collection from the Tennessee drainage in northern Alabama and southern Tennessee made by H.

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[4] *Nautil.,* 23, 1910, p. 117, footnote 2, and *Ann. Carnegie Mus.,* 8, 1912, p. 264.

[5] *Nautil.,* 31, 1917, p. 58.

[6] *Proc. Amer. Philos. Soc.,* 57, 1918, p. 521 ff.

[7] *Mem. Carnegie Mus.,* 8, 1919.

[8] The *greatest* length of the shell is sometimes in a diagonal direction, when the shell is "oblique"; but since the obliquity varies much individually, the length parallel to the ligament is selected. Previous authors (Lea for instance) have not strictly adhered to this rule, and thus we may explain certain discrepancies of the figures given in his text, and those taken from his illustrations. In my measurements, I have always taken Lea's illustrations as the standard.

H. Smith; and finally I had the privilege of examining upper Tennessee shells in the collection of Mr. B. Walker in Detroit, collected by C. C. Adams (particulars about these may be found in my paper on the upper Tennessee Naiades).

Of course, the shells collected at one and the same locality vary somewhat, and thus it was necessary to compute the average for each set. In some cases, only few specimens were at hand, in others, a great many of them. Thus I do not give, in the tables, the individual measurements, but only the extremes and the average. We shall see that this is entirely sufficient to establish the law. In each river, the localities are arranged from downstream upward, taking up the tributaries of the main stream generally in ascending order. The exact situation of each locality may be found on the map (page 258).

According to obesity, previous authors frequently have distinguished separate species, and often corresponding forms in different river-systems have received different specific names. Thus it has been a difficult task to bring order in the nomenclature, and I am compelled to devote considerable space to this. Since it will become apparent that the various groups of forms treated actually are *connected by intergrades,* each group should be regarded, taxonomically, as *one species.* But since, on the other hand, the extremes are often rather sharply contrasted, and since they very generally appear as geographical (or rather ecological) races, it is convenient and justified, to use the old specific names in a varietal (or subspecific) sense. On account of the existing intergrades it is difficult, even impossible, to draw sharp lines between these varieties, and the dividing lines selected by myself (according to percentage of diameter) may seem, and are, arbitrary: I have endeavored, in this respect, to preserve the older names as far as possible. Sometimes it was possible to distinguish only two forms, a swollen one and a flat one; in other cases, three have been admitted (an intermediate one being added to the two extremes). This latter course was made necessary in those instances, where the oldest name was given to an intergrading form.

GROUP OF FUSCONAIA SUBROTUNDA IN THE UPPER OHIO SYSTEM.

The following is the taxonomy of this group here accepted.

1. FUSCONAIA SUBROTUNDA (Lea).—Dia. 50 per cent. of length and over.

Unio subrotundus Lea. '31 (Ohio).—*Quadrula subrotunda* Simpson, '14, p. 892.[9]

Dia. (Lea): 60 per cent. Simpson gives: 44, 49, 51 per cent., but only the last one would belong here according to the definition accepted above.

Unoi politus Say, '34.—Synonym to *subrotunda* according to Simpson.

Dia. (Conrad, '37): 53 per cent.

Fusconaia leucogona (pars) Ortmann, Nautil. 27, '13, p. 89 (Elk River, W. Va.).

2. FUSCONAIA SUBROTUNDA KIRTLANDIANA (Lea).—Dia. less than 50 per cent.

Unio kirtlandianus Lea, '34 (Mahoning R., Ohio).—*Quadrula kirtlandiana* Simpson, '14, p. 891.

Dia. (Lea): 44 per cent.; (Simpson): 33, 38 per cent.

Fusconaia leucogona (pars) Ortmann, l. c.

Measurements taken from My Material.[10]

Loc.	No.	Max.	Min.	Av.	
Ohio River.					
Portsmouth	5	67	51	59	*subrot.*
Portland	4	52	49	51	*subrot.* (*kirtl.*)
Parkersburg	1	51	51	51	*subrot.*
St. Mary's	8	62	50	54	*subrot.*
Toronto	2	52	50	51	*subrot.*
Cooks Ferry	2	54	52	53	*subrot.*
Industry	9	57	42	47	*kirtl.* (*subrot.*)
Coraopolis	8	53	42	48	*kirtl.* (*subrot.*)

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[9] Simpson, C. T. A descriptive Catalogue of the Naiades, or Pearly Fresh-water Mussels. Detroit, 1914. All other references given without detil may be found in this work.

[10] The first column gives the locality; the second the number of specimens at hand; the third, fourth and fifth, the maximum, minimum, and average of the percentage of the diameter; and in the last column, the name of the variety represented is given. When several forms are present, the first name is that of the prevailing (average) form, the other (in parenthesis) that of the less abundant one.

Thus it appears that in the Ohio, between Portsmouth and Pittsburgh, there is a tendency to decrease the diameter in the upstream direction. The most swollen specimens, with the highest diameter, and the highest average of it, have been encountered at the lowermost station (Portsmouth), and the most compressed specimens, and the lowest average, at the two uppermost stations. This general law holds good also, when we now go up the *Allegheny River,* and enter *French Creek.* (In the Allegheny proper, above the mouth of French Creek, this species has not been found.)

Loc.	No.	Max.	Min.	Av.	
Allegheny River.					
Natrona	1	45	45	45	*kirtl.*
Aladdin	3	47	45	46	*kirtl.*
Godfrey	26	66	43	51	*subrot.* (*kirtl.*)
Johnetta	2	50	46	48	*kirtl.* (*subrot.*)
Kelly	113	54	38	47	*kirtl.* (*subrot.*)
Templeton	1	49	49	49	*kirtl.*
French Creek.					
Utica	4	43	40	42	*kirtl.*
Cochranton	8	49	33	42	*kirtl.*
Meadville	2	46	45	45.5	*kirtl.*
Cambridge Springs	2	44	43	43.5	*kirtl.*

Here we notice irregularities, indeed, in so far as, for instance at Godfrey, the percentage increases again, and remains only a little below 50 per cent. in the Allegheny, but sinks rather abruptly to a little above 40 per cent. in French Creek. The latter phenomenon may be due to the sudden decrease in the size of the streams. It should also be noticed that both the maxima and minima decrease in the upstream direction, and it always should be emphasized that the material from the various localities is not uniform as regards the number of specimens measured: thus irregularities should be encountered, and, of course, mathematical exactness cannot be expected in a biological object.

Taking all the shells together, beginning in the Ohio at Portsmouth, and going up the Allegheny to French Creek, we notice *the general decrease of the obesity:* the most swollen specimen was found at Portsmouth (67 per cent.); the most compressed one (33 per cent.) in French Creek. Specimens from the lower parts of the

Ohio have a diameter almost uniformly above 50 per cent.; in the region around Pittsburgh (in Ohio and Allegheny), it varies around 50 per cent.; and in French Creek it falls below 45 per cent. (always barring minor irregularities).

Already this first instance substantiates the general law propounded in the introduction: *in the larger rivers, these shells are more convex and swollen; in the headwaters, they are flat and compressed; and in the intermediate parts, the intergrades between the extremes are found.*

Under these circumstances it is, indeed, hard to draw a line between the two forms called *subrotunda* and *kirtlandiana*. According to measurements taken from Lea (Dia. 69 per cent.), there are specimens which are even more obese than any of those examined by myself (max. 67 per cent.), and these swollen forms differ very strikingly from those which have only 44 per cent. (as in Lea's type of *kirtlandiana*), or even less (falling to 33 per cent. according to Simpson and my material). In order to include *politus* Say in the synonymy of *subrotunda,* as Simpson has done, I have decided to draw the line at the diameter of 50 per cent., so that individuals with this diameter and over shall be called *Fusconaia subrotunda,* and individuals with the diameter less than 50 per cent. shall be called *Fusmonaia subrotunda kirtlandiana.* Thus it is evident that two of the shells of *subrotunda,* for which Simpson gives the measurements, having the diameter 44 and 49 per cent., fall under *kirtlandiana.*

This will bring almost all specimens in the Ohio below Pennsylvania under the main species, while all specimens in French Creek are the var. *kirtlandiana.* In the Pennsylvanian part of the Ohio, and in the Allegheny, we have the two forms associated, sometimes the one, sometimes the other prevailing, and the various sets from these localities should be separated accordingly. This is only what we should expect as the natural condition; and also, for practical purposes, this clears matters up, and brings sets together, which are rather uniform.

One additional circumstance should be pointed out. *The obesity of the shell changes a little with age, so that young shells, in the* *average, are more swollen than old ones.* This does not, however, introduce a serious error, since from most localities young and old shells are at hand. On the other hand, this serves to explain, in part, the irregularities observed. Very old shells are often unusually produced or elongated at the posterior end, and this tends to lower the percentage of the diameter. Just such shells have been found frequently in the Ohio near Pittsburgh, and these have, consequently, unduely depressed the average. Also the young shells, or, for that matter, shells of about the same size, when compared among themselves, show the decrease of the obesity in the upstream direction. The same phenomenon is found in other forms to be discussed later.

Fusocnaia subrotunda also enters several tributaries of the Ohio. First of all, we have it in Elk River in West Virginia (tributary to Kanawha). The Kanawha empties into the Ohio in a region where typical *subrotunda* is found. I have no material from this river. But in Elk River is a form, which I have called *F. subrotunda leucogona,* and which I have characterized as a "rather small and somewhat flattened *subrotunda,*" also differing by (mostly) pale soft parts and eggs. I doubt now the propriety of introducing a separate name for this form, for it might very well be included under both, *subrotunda* and *kirtlandiana,* these also having sometimes pale soft parts. The following table gives the measurements of the *Elk River* specimen.

Loc.	No.	Max.	Min.	Av.		
Shelton	12	52	45	49.5	*kirtl.*	(*subrot.*)
Gassaway	12	53	38	48	*kirtl.*	(*subrot.*)
Sutton	12	49	43	46	*kirtl.*	

The decrease of the average diameter is also here clearly shown, the maximum being found in the two lower stations (with specimens which would fall under *subrotunda*). The minimum has been observed in the middle station, but only in one individual, and another with the diameter of 41 per cent., while all the rest do not fall under 45 per cent. This is one of the irregularities which should be expected.

Another river which contains this species is *Beaver River* in

Pennsylvania. This is formed by two main branches, *Shenango* and *Mahoning,* which unite below Newcastle, at Mahoningtown. I shall begin with the only locality in the Beaver proper, then go up the Shenango to the mouth of Pymatuning Creek, and finally go up the Mahoning.

Loc.	No.	Max.	Min.	Av.		
Beaver River.						
Wampum	25	52	41	44	*kirtl.*	(*subrot.*)
Shenango River.						
Harbor Bridge	13	47	36	40	*kirtl.*	
Pulaski	18	49	40	44	*kirtl.*	
Sharpsville	4	48	35	43	*kirtl.*	
Clarksville	18	50	36	45	*kirtl.*	
Pymatuning Creek (mouth)	1	39	39	39	*kirtl.*	
Mahoning River (follows Wampum).						
Mahoningtown	51	52	37	44	*kirtl.*	(*subrot.*)
Coverts	6	47	40	43	*kirtl.*	
Edinburg	4	42	39	40	*kirtl.*	

In the Ohio, just below the mouth of the Beaver (at Industry), the diameter is 47 per cent. Thus the Beaver-shells are clearly less swollen. While all these specimens are rather uniform in diameter, it is seen that the lowest average is farthest upstream. Specimens with over 50 per cent. are found frequently only at the lowermost stations (Wampum and Manoningtown), and specimens with lowest diameter (below 40 per cent.) are most frequent farther up. The very high average at Clarksville (45 per cent.) is due to an unusual number of young specimens, which, as we have seen, tend to elevate the average; and the low average at Harbor Bridge is due to the fact that mostly large specimens are among them, which depress the figures.

It should be mentioned that the type-locality for *kirtlandiana* is in the "Mahoning River, Ohio," that is to say, farther up than any of my localities, and that the diameter as given by Lea's illustration is 44 per cent.

Thus nearly all of the shells from the Beaver drainage fall under *kirtlandiana.*

Finally, I have shells belonging here from the *Monongahela drainage.* At present, the Monongahela in Pennsylvania and parts of West Virginia (below Clarksville) is polluted, and its fauna is destroyed. I have older material, however, from one locality in the Monongahela proper; farther up, I collected some near the mouth of *Cheat River,* just at the state line; and at one locality in the headwaters (*West Fork River*). The measurements are as follows.

Loc.	No.	Max.	Min.	Av.	
Monongahela, Charleroi	13	61	48	53	*subrot.* (*kirtl.*)
Cheat, Cheat Haven	2	52	40	46	*kirtl.* (*subrot.*)
West Fork, Lynch Mines	2	44	41	42.5	*kirtl.*

This material is rather scanty; nevertheless the decrease in obesity in the upstream direction is clearly seen. The locality Charleroi has a higher percentage (63) than the next localities below in the Ohio (47 and 48 at Industry and Coraopolis), but agrees with that of Cooks Ferry. This, probably, is again due to the age of the shells. In the Ohio below Pittsburgh, giant specimens, with the length over 100 mm., are not uncommon, while among the shells from Charleroi there is not a single one over 100 mm. (largest 91 mm.).

Very probably, this law holds good also in other tributaries of the Ohio. I have not enough material to demonstrate this. In one case, that of the *Tuscarawas River* in Ohio, I have rather abundant material from the Holland collection, but, unfortunately, no exact localities are given; both forms, however, are represented in this river. From the *Levisa Fork Big Sandy River,* Prestonsburg, Floyd Co., Ky., I have a single specimen, the diameter of which is 50 per cent., that is to say, it is a *subrotunda* standing just at the lower limit, and close to *kirtlandiana,* and this would correspond to the station well up the river. From *Little Kanawha River,* Grantsville, Calhoun Co., W. Va., I have one specimen, the diameter of which is 43 per cent. this is the typical *kirtlandiana,* corresponding to the small size of this river.

All this serves to show that our contention is upheld, *that F. subrotunda and kirtlandiana are forms of the same species, differing only in obesity.* The former is the swollen form of the large rivers; the latter is the compressed form of the small streams. Both are connected by intergrades, and any line drawn between them must necessarily be artificial and arbitrary. It is advisable, however, to retain the old names in a varietal sense, for the extremes are rather strikingly different.

GROUP OF FUSCONAIA PILARIS IN THE UPPER TENNESSEE-DRAINAGE.

Fusconaia pilaris (Lea) is the representative of *F. subrotunda* in the upper Tennessee system, and it is extremely hard to distinguish the two. All I can say is that *pilaris* is a smaller shell than *subrotunda*, a character mentioned also by Simpson. For the rest, there is no difference, and it is actually impossible to tell younger *subrotunda* from *pilaris*, as is shown by the fact that *pilaris* repeatedly has been reported from the Ohio River. In the Tennessee River in northern Alabama, typical *subrotunda* is found, and I have specimens from this region. But since I have no material from this river between these parts and the vicinity of Knoxville, Tenn., I cannot discuss the relation of these two forms. They may pass into each other.

The *pilaris*-group of the upper Tennessee contains a number of nominal species which have been distinguished on entirely insufficient grounds. I have revised them[11] in the following way.

1. FUSCONAIA PILARIS (Lea).—D. 55 per cent. or over.

Unio pilaris Lea, '40 (French Broad and Holston).—*Quadrula pilaris* Simpson, '14, p. 893.

Dia. (Lea): 63 per cent. Simpson gives two measurements, 47 and 54 per cent., which, however, belong to the next form, which he unites with this.

Unio globatus Lea, '71 (Holston).—*Quadrula globata* Simpson, '14, p. 899.

Dia. (Lea): 68 per cent.; (Simpson): 67 per cent.

Quadrula andrewsæ Marsh, '02 (Holston).—*Quadrula andrewsi* Simpson, '14, p. 895.

Dia. (Simpson): 55 per cent.

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[11] *Proc. Amer. Philos. Soc.*, 57, '18, pp. 527–529.

Quadrula beauchampi Marsh, '02 (Little Tennessee and Holston).—Simpson, '14, p. 895.

Dia. (Simpson): 61 per cent.

2. Fusconaia pilaris lesueuriana (Lea).—Dia. 45–54 per cent.

Unio lesueurianus Lea, '40 (Caney Fork and Holston).—Synonym to *pilaris*, according to Simpson.

Dia. (Lea): 51 per cent.—Simpson's measurements of *pilaris* (47 and 54) belong here.

Quadrula flexuosa Simpson, '00 (Holston).—Simpson, '14, p. 887.

Dia. 51 per cent.

3. Fusconaia pilaris bursa-pastoris (Wright).—Dia. less than 45 per cent.

Unio bursa-pastoris Wright, '96 (Powell R., Va.).—*Quadrala bursa-pastoris* Simpson, '14, p. 890.

Dia. (Simpson): 35 per cent.

I shall follow the same scheme as before, and go up the Tennessee and the tributaries: Holston, Clinch, Powell, etc.

Loc.	No.	Max.	Min.	Av.	
Tennessee River.					
Knoxville	8	64	53	57	*pil.* (*les.*)
Holston River.					
McMillan	1	50	50	50	*les.*
Mascot	16	63	47	56	*pil.* (*les.*)
Hodges	2	53	51	52	*les.*
Turley Mill	4	56	43	47	*les.* (*pil.*) (*b.-p.*)
Noeton	7	60	48	51	*les.* (*pil.*)
Holston Station	7	54	47	51	*les.*
Church Hill	3	47	43	45	*les.* (*b.-p.*)
South Fork Holston River.					
Pactolus	10	49	39	45	*les.* (*b.-p.*)
Bluff City	5	45	39	42	*b.-p.* (*les.*)
Watauga River.					
Watauga	1	40	40	40	*b.-p.*
North Fork Holston River.					
Rotherwood	7	54	44	50	*les.* (*b.-p.*)
Holston Bridge	1	46	46	46	*les.*
Hilton	9	48	41	43	*b.-p.* (*les.*)
Mendota	1	38	38	38	*b.-p.*

It is interesting to observe that all three forms are found at Turley Mill.

This table shows that the diameter decreases in the upstream direction. There are slight irregularities, but the general law is distinctly expressed.

In the *Clinch River,* this is shown even more distinctly. The Clinch goes into the Tennessee below my lowermost locality at Knoxville, but my first station in the Clinch is a good distance up from the mouth.

Loc.	No.	Max.	Min.	Av.	
Clinch River.					
Solway	12	59	44	51	*les.* (*pil.*) (*b.-p.*)
Edgemoor	17	62	44	52	*les.* (*pil.*) (*b.-p.*)
Clinton	9	56	40	48	*les.* (*pil.*) (*b.-p.*)
Offutt	7	53	43	47	*les.* (*b.-p.*)
Agee	1	46	46	46	*les.*
Needham Ford	14	53	36	44	*b.-p.* (*les.*)
Black Fox Ford	6	45	36	40	*b.-p.* (*les.*)
Clinch River Station	5	44	35	40	*b.-p.*
Oakman	7	44	37	40	*b.-p.*
Sneedville	1	36	36	36	*b.-p.*
Kyle Ford	2	45	40	42.5	*b.-p.* (*les.*)
Horton Ford	1	37	37	37	*b.-p.*
Speers Ferry	3	40	38	39	*b.-p.*
Clinchport	12	46	35	40	*b.-p.* (*les.*)
St. Paul	3	38	36	37	*b.-p.*
Fink	2	41	40	40.5	*b.-p.*
Cleveland	7	37	34	36	*b.-p.*
Raven	11	40	33	36	*b.-p.*
Richland	10	41	35	37	*b.-p.*
Cedar Bluff	5	39	34	37	*b.-p.*

Powell River (Agee, just below has 46 per cent. = *les.*).

Loc.	No.	Max.	Min.	Av.	
Greens Ford	2	49	42	45.5	*les.* (*b.-p.*)
Combs	8	45	35	39	*b.-p.* (*les.*)
Arthur	4	44	34	40	*b.-p.*
Shawanee	4	49	38	42.5	*b.-p.* (*les.*)
Rose Hill	2	41	40	40.5	*b.-p.*
Jonesville	1	39	39	39	*b.-p.*
Dryden	3	43	36	39	*b.-p.*
Big Stone Gap	1	39	39	39	*b.-p.*

These tables do not need any further comment: barring certain local irregularities, which can be accounted for by scarcity of material, the law is clearly shown, that in the upstream direction the diameter decreases, and that it decreases very gradually. The conditions in the Holston, and chiefly in the Clinch and Powell are, indeed, classical.

It should be added that I have seen a single individual from *Little Tennessee River,* Coytee, Loudon Co., Tenn., which has the diameter of 58 per cent. (= *pilaris*). Little Tennessee goes into the Tennessee below Knoxville, and thus this agrees well with the figure for specimens from Knoxville (57 per cent.).

I further collected a large number of specimens in *French Broad River,* at Boyd Creek, Sevier Co., Tenn. This river unites with the Holston to form the Tennessee just above Knoxville. I have measured 16 specimens; the max. is 64 per cent.; the min. 47 per cent.; the av. 56 per cent. Also these figures are exactly what we should expect.

There is no question that all these shells are one and the same species, for which the name *pilaris,* as the oldest, should be used, and which changes in obesity from the large rivers towards the headwaters. Since Lea distinguished, at the same time, two forms which differ chiefly in being more or less swollen, the two names given by him (*pilaris* and *lesueuriana*) should be preserved in a varietal sense, and a third variety of great compression should be added, described much later by Wright as *bursa-pastoris.*

As *pilaris* corresponds to *subrotunda, bursa-pastoris* corresponds to *kirtlandiana* of the upper Ohio drainage. In fact, it is so close to it that Pilsbry and Rhoads[12] have identified specimens from *Watauga River* as *kirtlandiana.* I have serious doubts that the two forms can be kept apart, when the locality is unknown. In my large material I can see only one difference, that is, that *bursa-pastoris* is a smaller shell than *kirtlandiana,* and reaches a greater degree of compression. This opens a very pertinent question as to nomenclature, since also *pilaris* (and *lesueuriana*) apparently represent only a small race of *subrotunda.* I shall not go any further into this problem, which may necessitate some radical changes in our Naiad-nomenclature.

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[12] *Pr. Ac. Nat. Sci., Philad.,* 48, 1896, p. 502.

This much is certain, that *F. pilaris,* the representative form in the upper Tennessee of *F. subrotunda* from the Ohio, behaves exactly as *F. subrotunda,* but the headwaters-forms of the two, in the upper Tennessee and the upper Ohio drainages, although very similar, have no direct genetic connection, and undoubtedly have developed independently of each other.

GROUP OF FUSCONAIA FLAVA IN THE UPPER OHIO-DRAINAGE.

I classify the forms belonging here as follows.

1. FUSCONAIA FLAVA (Rafinesque).—Dia. less than 55 per cent.

Obliquaria flava Rafinesque, '20 (trib. of Kentucky, Salt, Green R.). —*Quadrula flava* Vanatta, Pr. Ac. Philad., '15, p. 557.

Dia. (Conrad, '37): 43 per cent.; (Vanatta): 39 per cent.

Unio rubiginosus Lea, '29 (Ohio).—*Quadrula rubiginosa* Simpson, '14, p. 872.

Dia. (Lea): 44 per cent.; (Simpson): 41, 34, 53 per cent.

2. FUSCONAIA FLAVA TRIGONA (Lea).—Dia. 55 per cent. and over.

Unio trigonus Lea, '31 (Ohio R., Cincinnati and Louisville).—Synonym to *Quadrula undata* (Barnes), according to Simpson, '14, p. 881.

Dia. (Lea): 63 per cent.

Probably also *U. undatus* Barnes, '23, belongs here. This form has been discussed by Walker (Nautil., 24, '10, p. 24), who says that it is the same as *trigonus.* He gives the diameter of 68 per cent. Simpson (l. c.), who follows him, gives it as 60, 61, and 76 per cent.

Walker and Simpson probably are right in regarding *trigonus* and *undatus* as synonyms, as far as it concerns obesity. However, I think that they differ in the development of the beaks, *undatus* having higher beaks, so that the outline is more triangular, while it is subtrapezoidal in *trigonus.* Of typical *undatus* I have no good material, and this form is not found in the upper Ohio. What I have from this region (vicinity of Pittsburgh and upwards) represents, in the more obese form, distinctly the shell called by Lea *trigonus,* and thus I shall use this name, and restrict myself to the two forms *flava* and *trigona,* and their interrelation, leaving the decision as to the standing of *undata* to further investigation. According to Utterback,[13] the latter also passes into *trigona.*

Loc.	No.	Max.	Min.	Av.	
Ohio River.					
Coraopolis	14	63	49	54	*flav.* (*trig.*)
Monongahela River.					
Elizabeth	1	49	49	49	*flav.*
Charleroi	8	66	50	56	*trig.* (*flav.*)
Millsboro	1	47	47	47	*flav.*

The following are tributaries going into the Monongahela at and above Millsboro.

Loc.	No.	Max.	Min.	Av.	
N. Fork Ten Mile Creek, Amity..	2	48	48	48	*flav.*
S. Fk. Ten Mile Cr., Waynesburg	6	48	41	44	*flav.*
Dunkard Creek, Wiley	2	47	43	45	*flav.*
Dunkard Creek, Mt. Morris	10	50	41	47	*flav.*

The law is again apparent here: the most compressed forms are found in the tributaries, the most swollen ones in the larger river.

Going up the *Allegheny River,* and ascending one of its tributaries, *Crooked Creek,* the law is not so clearly shown for the reason that this form is rare in the Allegheny proper, and is entirely missing in the headwaters. Yet indications are seen in Crooked Creek.

Loc.	No.	Max.	Min.	Av.	
Allegheny River.					
Godfrey	3	44	41	43	*flav.*
Johnetta	2	55	50	53	*flav.* (*trig.*)
Kelly	2	42	42	42	*flav.*
Crooked Creek.					
Rosston	29	51	38	43	*flav.*
South Bend	2	41	41	41	*flav.*
Creekside	8	44	38	41	*flav.*

That the compressed form is the one found in smaller streams, is also shown by several isolated sets from other tributaries of the Ohio, which have been measured, and the following are of interest.

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[13] *Amer. Midland Naturalist* (Notre Dame, Ind.), 4, '16, p. 21.

Loc.	No.	Max.	Min.	Av.	
Little Kanawha River, Burnsville.	12	55	40	44	*flav.* (*trig.*)
Raccoon Creek, New Sheffield ...	9	46	42	43	*flav.*
Chartiers Creek, Carnegie	3	46	40	44	*flav.*

Since the compressed form of the headwaters (*flava*) very gradually passes into the more swollen form of the larger rivers (*trigona*), the distinguishing line between them necessarily must be arbitrary. I have adopted 55 per cent. as the limit, so that shells with the diameter of 55 per cent. and over are called *trigona,* while shells with less than 55 per cent. are *flava.*

GROUP OF FUSCONAIA CUNEOLUS IN THE UPPER TENNESSEE-SYSTEM.

Fusconaia flava and *trigona* are absent in the upper Tennessee-drainage, but they are represented there by two allied species, which agree in general shape and in anatomy with the Ohio shells, but differ from them, and from each other, chiefly in the color of the epidermis. They appear to be good species, for they do not run into the *flava*-type anywhere, and I also have never found evidence that they run into each other. These shells are *F. cuneolus* and *F. edgariana.* In both of them, however, the same phenomenon as regards obesity is observed.

F. cuneolus has the following forms and synonyms.[14]

1. FUSCONAIA CUNEOLUS (Lea).—Dia. less than 50 per cent.

Unio cuneolus Lea, '40 (Holston R.).—*Pleurobema cuneolus* Simpson, '14, p. 743.

Dia (Lea): 43 per cent.; (Simpson): 42 and 46 per cent.

2. FUSCONAIA CUNEOLUS APPRESSA (Lea.)—Dia. 50 per cent. or over.

Unio appressus Lea, '71 (Tennesse R., Tuscumbia; Holston R.).—*Pleurobema appressa* Simpson, '00, p. 749.

Dia. (Lea): 52 per cent.

Unio tuscumbiensis Lea, '71 (Tuscumbia; Holston R.).—*Pleurobema tuscumbiensis* Simpson, 14, p. 748.

Dia. (Lea): 56 per cent.; (Simpson): 56 and 58 per cent.

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[14] See *Pr. Amer. Philos. Soc.,* 57, '18, pp. 530, 531.

Unio flavidus Lea, '72 (Clinch R., Anderson Co., Tenn.; Holston R.; N. Ala.).—Synonym to *Pl. tuscumbiensis,* according to Simpson, l. c.

Dia. (Lea): 52 per cent.

I have measured the following material.

Loc.	No.	Max.	Min.	Av.	
Tennessee River.					
Chota Shoals	4	66	51	61	*appr.*
Holston River.					
Turley Mill	1	46	46	46	*cun.*
Noeton	10	59	45	51	*appr.* (*cun.*)
Holston Station	2	47	45	46	*cun.*
Austin Mill	3	54	45	48	*cun.* (*appr.*)
North Fork Holston River.					
Rotherwood	10	45	39	41	*cun.*
Hilton	8	43	36	40	*cun.*
Mendota	8	46	38	41	*cun.*

The general rule, from the Tennessee up the Holston, is seen. Irregularities and more sudden changes (from the Tennessee to the Holston, and from the latter to the North Fork) may be accounted for, on the one hand, by scarcity of material, or, on the other, by the sudden transition from a larger river to a smaller one.

I leave out some material collected in tributaries of the Tennessee and Holston, because it is fragmentary: but I should say that it does not conflict with the rule. From the *Clinch River,* I am able to offer the following table.

Loc.	No.	Max.	Min.	Av.	
Clinch River.					
Solway	1	55	55	55	*appr.*
Clinton	7	57	47	51	*appr.* (*cun.*)
Offutt	1	52	52	52	*appr.*
Black Fox Ford	3	45	40	43	*cun.*
Clinch River Station	6	45	40	43	*cun.*
Oakman	7	49	39	44	*cun.*
Horton Ford	1	39	39	39	*cun.*
Speers Ferry	9	42	36	40	*cun.*
Clinchport	6	44	38	41	*cun.*

The sudden change of obesity between Offutt and Black Fox Ford undoubtedly is due to the fact that a long stretch of the river intervenes from which no shells are at hand, and that above Offutt the Powell flows into the Clinch, the latter thus suddenly decreasing in size.

Material from the Powell is scanty, but it fits into the scheme. It is thus clear that also the *cuneolus*-group is subject to the law. It also holds good, as far as my material goes, in the Tennessee and its tributaries in northern Alabama, where this type of shells also seems to be abundant.

GROUP OF FUSCONAIA EDGARIANA IN THE UPPER TENNESSEE-SYSTEM.

I distinguish the following two forms, but use the specific name of *edgariana* (see *F. cor,* Ortmann, '18, pp. 532, 533).

1. FUSCONAIA EDGARIANA (Lea).—Dia. 50 per cent. or over.

Unio edgarianus Lea, '40 (Holston R., Tenn.; Tennessee R., Florence, Ala.).—*Pleurobema edgarianum* Simpson, '14, p. 741.
Dia. (Lea): 64 per cent.; (Simpson): 58, 69, 76 per cent.

Unio obuncus Lea, '71 (Tuscumbia, Ala.; Holston R., Tenn.).—Synonym to *edgarianum,* according to Simpson.
Dia. (Lea): 53 per cent.

Unio andersonensis Lea. '72 (Holston R.; Clinch R., Anderson Co., Tenn.).—Synonym to *edgarianum,* according to Simpson.
Dia. (Lea): 76 per cent.

2. FUSCONAIA EDGARIANA ANALOGA (Ortmann).—Dia. less than 50 per cent.

Fusconaia cor analoga Ortmann, '18, p. 533 (Clinch R., Speers Ferry).

My material from *Clinch River* has furnished the following figures.

Loc.	No.	Max.	Min.	Av.	
Clinch River.					
Edgemoor	1	58	58	58	*edgar.*
Needham Ford	2	51	42	46.5	*anal.* (*edgar.*)
Clinch River Station	2	48	47	47.5	*anal.*
Sneedville	1	49	49	49	*anal.*
Church Ford	1	42	42	42	*anal.*
Speers Ferry	8	49	43	46	*anal.*
Clinchport	6	45	41	43	*anal.*
St. Paul	7	45	40	43	*anal.*
Fink	2	48	41	45	*anal.*
Cleveland	6	44	40	42	*anal.*

The sudden jump between Edgemoor and Needham Ford is explained by the long distance between these two points.

In the *Powell River,* this shell is also found, and material is at hand from two places, Combs and Rose Hill. At the former place, the average diameter is 42 per cent., at the latter, 43 per cent. Here the lowest percentage has been found to be 38.

I did not collect shells of this type in the Holston below the forks, which is quite a remarkable fact. But the flat type turns up again in the North Fork, from Rotherwood to Holston P. O. Here the diameter lies between 41 and 48 per cent., and there is no apparent change in this comparatively short stretch of river.

Three shells from the *Tennessee* at Florence, Ala., have the dia. 55, 70, 70 per cent., with the average of 65, thus being more swollen than any shells from the upper Tennessee region. From a tributary some distance farther up, *Paint Rock River,* I have the following table.

Loc.	No.	Max.	Min.	Av.	
Paint Rock	10	54	47	51	*edgar.* (*anal.*)
Trenton	6	54	47	52	*edgar.* (*anal.*)
Princeton	1	49	49	49	*anal.*

This series may appear as unreliable, since the uppermost station contains only one shell; yet the fact is evident that the Paint-Rock-River-shells are less obese than those from the Tennessee below.

Although, on the whole, my material of the *edgariana*-group is somewhat fragmentary, the law is distinctly seen, chiefly in a portion of the Clinch River, from Needham Ford upwards, where conditions are typical. These are perfectly analogous to those observed in the *cuneolus*-group, and thus we are justified to distinguish also here two varieties, a swollen river form, and a flat headwaters-form, although the latter has not been named previously.

GROUP OF FUSCONAIA BARNESIANA IN THE UPPER TENNESSEE SYSTEM.

I have treated of this group previously,[15] and have given an account of its taxonomy. Thus it suffices here to repeat only the general results, and to support them by tables of measurements. The material of this species is rather rich, and I shall not give the measurements of all of it, but shall restrict myself to selected examples which show the law clearly.

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[15] *Nautil.,* 31, 1917, p. 58 ff.

I have distinguished here three forms.

1. Fusconaia barnesiana (Lea).—Dia. 40–49 per cent.

2. Fusconaia barnesiana bigbyensis (Lea).—Dia. less than 40 per cent.

3. Fusconaia barnesiana tumescens (Lea).—Dia. 30 per cent. or over.

I first give the material from three large rivers in the vicinity of Knoxville.

Loc.	No.	Max.	Min.	Av.	
Tennessee River, Little R. Shoals.	1	57	57	57	*tum.*
Little Tenn. River, Monroe Co. ..	3	57	51	54	*tum.*
French Broad River, Boyd Creek.	5	55	45	50	*tum.* (*barn.*)
Holston River.					
Mascot	1	48	48	48	*barn.*
Hodges	5	50	41	46	*barn.* (*tum.*)
Turley Mill	1	51	51	51	*tum.*
Noeton	5	52	45	49	*barn.* (*tum.*)
Holston Station	2	48	46	47	*barn.*
Austin Mill	1	40	40	40	*barn.*
South Fork Holston River.					
Pactolus	3	45	42	43	*barn.*
Bluff City	8	42	36	39	*bigb.* (*barn.*)
Emmett	8	39	35	37	*bigb.*
Barron	1	34	34	34	*bigb.*
Middle Fork Holston River.					
Chilhowie	3	37	35	36	*bigb.*

North Fork Holston River (next station below, Austin Mill, has av. 40 per cent. = *barn.*).

Loc.	No.	Max.	Min.	Av.	
Rotherwood	8	43	38	40	*barn.* (*bigb.*)
Mendota	4	41	36	39	*bigb.* (*barn.*)
Holston P. O.	5	40	35	37	*bigb.* (*barn.*)
Saltville	7	39	34	37	*bigb.*

Big Mocasin Creek (next station below, Rotherwood, has av. 40 per cent.).

Loc.	No.	Max.	Min.	Av.	
Moccasin Gap	10	40	32	37	*bigb.* (*barn.*)
Willow Springs	2	38	35	36.5	*bigb.*

It hardly needs to be pointed out that, beginning in the large rivers, *tumescens* passes gradually into *barnesiana,* and farther up, into *bigbyensis.* This is one of the best and most convincing series.

In *Clinch River,* conditions are similar, but the only specimen from the lowermost station (Solway) makes an exception, but a rather striking one. We may however, very well disregard it, and take it simply for an abnormal case. With the next station above it (Edgemoor), the normal condition is seen to begin.

Loc.	No.	Max.	Min.	Av.	
Clinch River.					
Solway	1	38	38	38	*bigb.*
Edgemoor	4	52	49	50	*tum.* (*barn.*)
Clinton	1	45	45	45	*barn.*
Walker Ford	2	49	46	47.5	*barn.*
Kyle Ford	1	41	41	41	*barn.*
Clinchport	1	36	36	36	*bigb.*
St. Paul	1	35	35	35	*bigb.*
Fink	1	38	38	38	*bigb.*
Raven	6	38	32	36	*bigb.*
Richland	12	40	33	36	*bigb.* (*barn.*)
Cedar Bluff	10	39	32	36	*bigb.*
Tazewell	1	39	39	39	*bigb.*

Powell River (next station below is Clinton, with 45 per cent. = barn.).

Loc.	No.	Max.	Min.	Av.	
Greens Ford	2	40	40	40	*barn.*
Combs	4	37	36	37	*bigb.*
Rose Hill	1	37	37	37	*bigb.*
Dryden	7	41	36	39	*bigb.* (*barn.*)
Big Stone Gap	12	41	31	36	*bigb.* (*barn.*)

No comment is necessary, except that it should be noted that, in this species, the intermediate form (*barnesiana*) turns up, occasionally, way up in the headwaters. This, of course, is due to the fact that the limits drawn between the three forms are very narrow.

In some of the tributaries of the upper Tennessee, *tumescens*. according to my material, passes only into *barnesiana,* without the most compressed form of *bigbyensis* being well represented. This is seen, for instance, in *Little Pigeon River* at Sevierville, a tributary to the *French Broad.* The latter, at Boyd Creek possesses *tumescens* with the average diameter of 50 per cent., with an admixture of some specimens of *barnesiana*. From Sevierville, I have ten specimens, ranging from 45 to 38 per cent., the average being 42 per cent., thus representing *barnesiana* with an interspersing of a few *bigbyensis*. I have no doubt, however, that, if there was any material from farther up stream, pure *bigbyensis* would appear.

Finally, the same conditions obtain in the Tennessee drainage in northern Alabama. In the *Tennessee River* at Florence is a form (12 specimens measured) in which the diameter ranges from 64 to 50 per cent., with the average at 56 per cent. This is pure *tumescens*. In the tributaries we find mostly the more compressed forms of the *barnesiana*- and *bigbyensis*-type, so, for instance, in *Elk River,* at Fayetteville (1 specimen), a form with the diameter of 44 per cent. (*barnesiana*), and farther up, at Estill Springs (8 specimens), a form ranging from 40 to 35 per cent., with the average of 38 per cent., which corresponds to *bigbyensis*.

Thus the contention is substantiated, that *tumescens* of the large rivers passes through *barnesiana* into *bigbyensis* of the headwaters.

GROUP OF AMBLEMA PERUVIANA (LAMARCK).

The extremes of this group of forms are marked by *Amblema peruviana* (Lam.) (= *Quadrula plicata* Simpson, '14, p. 814) and *Amblema costata* (Raf.) (= *Quadrula undulata* (Barn.) Simpson, p. 819). But there are other described "species" which fall into this group.

Wilson and Clark (1914) and Utterback (1916) have referred to these as showing the same phenomenon of a swollen form inhabiting the large rivers, and a flat one in the smaller streams (Cumberland and Osage River systems). I have no doubt that this is correct, and that it applies also to other rivers.

According to my experience, there is no question that specimens of *A. costata* in the Ohio River below Pittsburgh are more obese than the greatly compressed specimens found, for instance, in the Beaver and upper Allegheny drainages. However, I do not possess sufficient material from the middle and lower Ohio, to show the actual transition into *peruviana*. Also in the Tennessee-system, I did not go far enough down to reach the range of the latter: what I have found in the Knoxville region, and what I have from the Tennessee in northern Alabama, should all be classed with *A. costata.*

QUADRULA PUSTULOSA (Lea) (Simpson, '14, p. 848).

This is a species which generally avoids smaller streams, both in the Ohio and upper Tennessee drainages. Consequently, not much difference is observed in obesity. Nevertheless a slight indication of our law is seen in so far, as the most compressed individuals come from the most extreme stations in the upstream direction.

Generally speaking, in the Ohio and Tennessee systems, this species has a diameter between 50 and 70 per cent. Specimens falling under 50 per cent. are at hand from the following localities.

Licking Riv., Farmer.—Four specimens, dia. 47–45 per cent., average: 46 per cent.

Big Sandy Riv., Prestonsburg.—One among three specimens has the dia. of 44 per cent., the others have 50 and 52 per cent.

Pocatalico Riv., Raymond City.—Two specimens, dia. 48 and 45 per cent.

Little Kanawha Riv., Burnsville.—One specimen with 46 per cent. (another with 50 per cent.).

Allegheny Riv., Kelly.—One specimen with 49 per cent. among others more obese.

Cheat Riv., Cheat Haven.—One specimen with 48 per cent., and two others more obese.

All these stations are well upstream, and in no case, this species has been found above these points. Thus it is seen, that unusually flattened individuals turn up only in smaller streams or at the uppermost limit of the distribution. In the Tennessee system, no specimens under 50 per cent in diameter have been found.

QUADRULA METANEVRA (Rafinesque), and var. WARDI (Lea). Simpson, '14, pp. 834, 835.

The form *wardi* has been separated from typical *metanevra* because of its greater compression and greater smoothness, the large knobs, so characteristic for the main species, being absent or very slightly developed.

The true *metanevra* is restricted mainly to larger rivers. But occasionally it goes into smaller rivers, but hardly ever into the headwaters. It has been reported repeatedly from rather small streams, but then it was generally represented by the var. *wardi*. The original localities of the latter are *Walhonding River,* Ohio (tributary to Tuscarawas); *Wapsipinicon River* (Wassepinicon), Iowa; and *Coal River,* Logan Co., Va. (Coal River is now in Kanawha and Boone Cos., W. Va.). Three specimens from the latter locality were in the Hartman collection, and are now in the Carnegie Museum.

Sterki[16] reports *wardi* from *Sugar Creek,* another tributary of Tuscarawas River.

Aside from the types of *wardi* from Coal River, the Carnegie Museum possesses this form from the Ohio, Monongahela and Allegheny Rivers in the vicinity of Pittsburgh. But these specimens are not very typical, are rare, and intergrade with the normal *metanevra.* They are found, however, at and near the upstream limit of the distribution of the species. A rather good specimen of *wardi* comes from the *Little Kanawha River* at Burnsville. This again is a smaller stream.

Thus the tendency is observed, when the species enters smaller streams, to develop a compressed variety. But, in addition, this variety inclines to obliterate a peculiar sculpture, very characteristic for the main species, that of large knobs upon the surface of the shell. This should be kept in mind.

QUADRULA CYLINDRICA (Say). Simpson, '14, p. 832.

This widely distributed species ordinarily is strongly nodulous, with great knobs upon the posterior ridge, and the shell is generally much swollen. Its characters are rather uniform over the range.

However in the headwaters of the Ohio River, in Ohio and Pennsylvania, and in the upper Tennessee-region, two peculiar small-stream-races have developed. In the *Tuscarawas River,* in *Beaver River,* and *French Creek,* there is a remarkably compressed form, which, in addition, is practically smooth, having lost not only the large knobs, but also the nodules.[17] It hardly, however, forms a distinct race here, being rare, and passing insensibly into the normal type.

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[16] *Proc. Ohio Acad. Sci.,* 4, 1907.

In the *upper Tennessee;* there is an analogous form, also greatly compressed, and without the large knobs. It is, however, not smooth, but thickly covered with small nodules, even more so than the normal form. It has been called var. *strigillata* (Wright). Simpson (l. c.) does not accept this, because there is an "absolute graduation" to this form. Yet in the *upper Clinch,* from the Tennessee-Virginia state line upward, this variety becomes a pure race, which is very striking. It is also in Powell River and the North Fork Holston, but not so well developed.

In this instance, it is clearly seen that analogous, compressed forms are being developed independently in the upper Ohio and the upper Tennessee systems, and their independence is shown by the difference in the character of the nodules: the one is practically smooth, the other strongly nodulous. But in the disappearance of the large knobs they agree again.

I shall give here the measurements of the form in the *Clinch River.* In the last column, in this case, the name given refers to the development of the large knobs.

Loc.	No.	Max.	Min.	Av.	
Edgemoor	3	35	34	35	*cyl.*
Clinton	2	41	31	39	*cyl.*
Clinch River Station	6	39	34	36	*cyl.*
Speers Ferry	2	38	34	36	*cyl.*
Clinchport	5	35	32	33	*cyl.* (*strig.*)
Fink	1	31	31	31	*cyl.-strig.*
Cleveland	6	35	28	31	*strig.*
Raven	2	30	30	30	*strig.*
Richland	4	31	28	30	*strig.*
Cedar Bluff	1	27	27	27	*strig.*

ROTUNDARIA TUBERCULATA (Rafinesque), and R. GRANIFERA (Lea).
Quadrula tub. and gran. Simpson, '14, pp. 903, 905.

According to Wilson and Clark,[18] these two forms show, in the Cumberland River, the phenomenon that the swollen form (*grani-*

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[17] Sterki, *Pr. Ohio Ac.,* 4, '07, p. 390, mentions this form first.

[18] L. c., '14, p. 63.

fera) of the lower parts of the river passes gradually into the more compressed form (*tuberculata*) of the headwaters. I have not sufficient material to substantiate this by measurements, since all my material, from the middle Ohio upwards, and from the upper Tennessee, clearly belongs to the compressed *tuberculata*-type. But the general rule, at least, is thus confirmed, that the swollen form, *granifera,* is not found in the upper course of these rivers.

GROUP OF LEXINGTONIA DOLABELLOIDES IN THE UPPER TENNESSEE-SYSTEM.

The *dolabelloides*-group is common in the upper Tennessee, and also in the Tennessee-drainage in Alabama, and I again distinguish a swollen and a compressed form, the first in the larger rivers, the second in the headwaters. They pass gradually into each other, and the line drawn between them, at the diameter of 50 per cent., again is artificial. The nomenclature and synonymy is as follows:[19]

1. LEXINGTON DOLABELLOIDES (Lea).—Dia. 50 per cent. or over.

Unio dolabelloides Lea, '40 (Holston R., Tenn.).—*Pleurobema dol.* Simpson, '14, p. 752.
Dia. (Lea): 63 per cent.; (Simpson): 67 and 71 per cent.

Unio thorntoni Lea, '57 (Tuscumbia, Ala.).—Recognized as synonym by Simpson.
Dia. (Lea): 66 per cent.

Unio mooresianus Lea, '57 (Tuscumbia, Ala.).—Synonym, according to Simpson.
Dia. (Lea): 67 per cent.

Unio recurvatus Lea, '71 (Tennessee R.; Holston R.).—Synonym, according to Simpson.
Dia. (Lea): 63 per cent.

Uino circumactus Lea, '71 (Florence, Ala.; Holston R., Tenn.).—Synonym, according to Simpson.
Dia. (Lea): 58 per cent.

Unio subglobatus Lea, '71 (Florence, Ala.; Nashville, Tenn.).—Synonym, according to Simpson.
Dia. (Lea): 73 per cent.

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[19] See Ortmann, *Proc. Amer. Philos. Soc.,* 57, '18, pp. 545, 546.

2. LEXINGTONIA DOLABELLOIDES CONRADI (Vanatta).—Dia. less than 50 per cent.

Unio maculatus Conrad, '84 (Elk and Flint R., Ala.).—*Pleurobema maculatum* Simpson, '14, p. 737.

Dia. (Simpson) : 46 per cent.

Pleurobema appressum Simpson, '14, p. 747 (Tuscumbia, Ala.; Tennessee and Holston R., Tnnn.).

Dia. 47 per cent.

I submit here the following tables:

Loc.	No.	Max.	Min.	Av.	
Tennessee River.					
Florence	4	71	62	67	*dolab.*
Bridgeport	5	68	54	60	*dolab.*
Rathburn	1	74	74	74	*dolab.*
French Broad River, Boyd Creek.	2	61	59	60	*dolab.*
Clinch River.					
Solway	1	50	50	50	*dolab.*
Clinton	4	54	49	52	*dolab.* (*conr.*)
Agee	1	50	50	50	*dolab.*
Clinch River Station	1	44	44	44	*conr.*
Clinchport	1	42	42	42	*conr.*
St. Paul	1	45	45	45	*conr.*
Cleveland	5	40	39	40	*conr.*
Raven	6	39	34	36	*conr.*
Richland	2	38	36	37	*conr.*
Cedar Bluff	2	37	36	36.5	*conr.*

Similar conditions prevail in *Powell River,* where no *dolabelloides* have been met with, and where the percentage of *conradi* drops to 37 at Big Stone Gap.

Remarkably enough, I did not find this shell in the *Holston* proper (a case parallel to that of *Fusconaia edgariana*), but it is present again, in the shape of *conradi,* in *North* and *South Fork Holston,* and again the law is evident here. This is shown in the following table.

Loc.	No.	Max.	Min.	Av.	
South Fork Holston River.					
Bluff City	4	43	40	41	*conr.*
Emmett	1	42	42	42	*conr.*
Fish Dam	1	37	37	37	*conr.*

North Fork Holston River.					
Rotherwood	1	40	40	40	*conr.*
Hilton	2	42	41	41.5	*conr.*
Mendota	8	45	36	40	*conr.*
Saltville	8	40	36	37	*conr.*

Finally, I am able to tabulate the conditions in *Paint Rock River* in Alabama. It should be remembered that, in the main river in this region, *dolabelloides* is present with the average dia. of 67 and 60 per cent., and the minimum of 54 per cent.

Loc.	No.	Max.	Min.	Av.	
New Hope	10	64	49	57	*dolab.* (*conr.*)
Paint Rock	10	57	38	45	*conr.* (*dolab.*)
Princeton	7	44	38	40	*conr.*

This last series completely connects the two forms, which connection was not so evident in the lower Clinch on account of the scarcity of material.

GROUP OF PLEUROBEMA CORDATUM IN THE UPPER OHIO-DRAINAGE.

This is an extremely difficult and polymorphous group on account of the complexity of conditions and the variability of other characters of the shell, besides obesity. I have indicated, in a general way, the main phases of this species.[20] But most of them may be dismissed for our present purposes. Yet there are two of them, *Pl. cordatum catillus* and *Pl. cordatum coccineum,* which clearly submit to the law, as will be demonstrated in the tables.

The synonymy of these forms is as follows (It should be noted that I call the main species *cordatus* (Rafinesque), and not *obliquum* (Lamarck): the reason for so doing will be given elsewhere).

1. PLEUROBEMA CORDATUM CATILLUS (Conrad).—Dia. 50 per cent. or over.

Unio catillus Conrad, '36 (Scioto R., Ohio).

Dia. (Conrad): 51 per cent.

Unio solidus Lea, '38 (Ohio R., Cincinnati; Mahoning R., Ohio).—*Quadrula solida* Simpson, '14, p. 885.

Dia. (Lea): 60 per cent. Of the four specimens measured by Simpson, only two belong here with the Dia. 58 and 59 per cent.

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[20] Ortmann, '18, p. 547 ff.

Unio coccineus Lea, '38 (Ohio R., Marietta; Mahoning R., Ohio; Columbus, Ohio).

Dia.: 53 per cent.

Unio fulgidus Lea, '45 (Alexandria, La., probably a mistake).

Dia.: 60 per cent.

2. Pleurobema cordatum coccineum (Conrad).—Dia. less than 50 per cent.

Unio coccineus Conrad, '36 (Mahoning R., near Pittsburgh).—*Quadrula coccinea* Simpson, '14, p. 883.

Dia. (Conrad) : 37 per cent.; (Simpson) : 43, 46 per cent.

Loc.	No.	Max.	Min.	Av.	
Ohio River.					
Portsmouth	2	67	56	61.5	*cat.*
Portland	3	64	55	60	*cat.*
St. Mary's	4	67	59	63	*cat.*
Toronto	6	62	54	58	*cat.*
Cooks Ferry	14	65	50	57	*cat.*
Industry	16	64	52	57	*cat.*
Coraopolis	1	51	51	51	*cat.*
Allegheny River.					
Natrona	1	56	56	56	*cat.*
Aladdin	5	56	53	54	*cat.*
Godfrey	22	63	41	54	*cat.* (*cocc.*)
Johnetta	1	55	55	55	*cat.*
Kelly	67	62	40	51	*cat.* (*cocc.*)
Templeton	3	53	49	51	*cat.* (*cocc.*)
Walnut Bend	1	56	56	56	*cat.*
Tionesta	1	47	47	47	*cocc.*
Hickory	3	54	45	49	*cocc.* (*cat.*)
Warren	2	54	49	51.5	*cat.* (*cocc.*)
Larabee	12	51	44	47	*cocc.* (*cat.*)

Thus *catillus* does not entirely disappear in the headwaters of the Allegheny River. This is different in *French Creek*, which goes into the Allegheny above the station of Templeton in the last table, where the average diameter is 51 per cent.

Loc.	No.	Max.	Min.	Av.	
French Creek (follows Templeton).					
Utica	3	52	35	43	*cocc.* (*cat.*)
Cambridge Springs	6	45	37	42	*cocc.*
Conneauttee Creek, Edinboro	1	41	41	41	*cocc.*
Leboeuf Creek, Waterford	3	43	38	40	*cocc.*

I have also a very interesting series from the *Beaver drainage.* Just below the mouth of Beaver River, in the Ohio at Industry, pure *catillus* is present with the average diameter of 57 per cent.

Loc.	No.	Max.	Min.	Av.	
Beaver River.					
Wampum	14	61	48	53	*cat.* (*cocc.*)
Mahoning River.					
Mahoningtown	3	53	46	50	*cat.* (*cocc.*)
Coverts	1	50	50	50	*cat.*
Leavittsburgh	3	49	46	47	*cocc.*
Newton Falls	1	41	41	41	*cocc.*
Shenango River (follows Wampum).					
Harbor Bridge	3	48	43	46	*cocc.*
Pulaski	5	45	41	43	*cocc.*
Sharpsville	1	43	43	43	*cocc.*
Clarksville	9	52	41	47	*cocc.* (*cat.*)
Shenango	5	49	42	46	*cocc.*
Jamestown	17	48	37	43	*cocc.*

The elevation of the diameter at Clarksville is due to the presence of a number of quite young specimens. We have learned, under the group of *Fusconaia subrotunda,* that the diameter of young shells is comparatively greater. Older individuals at this locality are all pure *coccineum.*

Even in a small creek like the *Neshannock,* the law becomes visible.

Loc.	No.	Max.	Min.	Av.	
Eastbrook	8	43	36	40	*cocc.*
Neshannock Falls	3	48	35	41	*cocc.*
Volant	4	42	39	40	*cocc.*
Leesburg	4	40	36	38	*cocc.*

Similar conditions prevail in the *Monongahela drainage.* At Charleroi, the form *catillus* is rather pure. From farther up I have only scanty material, but at the mouth of *Cheat River,* at Cheat Haven, *catillus* is present (diameter about 50 per cent. or slightly more). From the West Fork River I have only specimens of typical *coccineum,* all with the diameter below 50 per cent.

GROUP OF PLEUROBEMA OVIFORME IN THE UPPER TENESSEE-DRAINAGE.

Great confusion has prevailed hitherto with regard to the shells belonging here. In a previous paper I have tried to bring order into this group,[21] and have divided it into three subspecies, because the oldest name given was applied to a form intergrading between the extremes. The synonymy is as follows.

1. PLEUROBEMA OVIFORME (Conrad).—Dia. 40 to 49 per cent. of length.

Unio oviformis Conrad, '34 (Tennessee).—*Pleurobema oviforme* Simpson, '14, p. 745.

Dia. (Simpson) : 43 per cent.

Unio ravenelianus Lea, '34 (French Broad R., Asheville, N. Car.). —*Pleurobema rav.* Simpson, '14, p. 796.

Dia. (Lea) : 43 per cent.; (Simpson) : 40 and 43 per cent. Another specimen measured by the latter has 50 per cent.

Unio lesleyi Lea, '60 (Kentucky, Tennessee).—*Pleurobema lesl.* Simpson, '14, p. 744.

Dia. (Lea) : 43 per cent. Specimens measured by Simpson give 31 and 39 per cent., and, consequently, do not belong here.

Unio ornatus Lea, '61 (Alabama).—*Pleurobema orn.* Simpson, '14, p. 746.

Dia. (Lea) : 43 per cent.; (Simpson, supposed type) : 44 per cent.

Unio clinchensis Lea, '67 (Clinch, French Broad, Holston).—*Pleurobema clinch.* Simpson, '14, p. 743.

Dia. (Lea and Simpson) : 44 per cent.

Unio conasaugaënsis Lea, '72 (Conasauga Cr., Monroe Co., Tenn.), —*Pleurobema con.* Simpson, '14, p. 800.

Dia. (Lea) : 45 per cent.; (Simpson) : 40 per cent.

2. PLEUROBEMA OVIFORME ARGENTEUM (Lea).—Dia. less than 40 per cent.

Unio argenteus Lea, '41 (Holston R., Tenn.).—*Pleurobema arg.* Simpson, '14, p. 798.

Dia. (Lea) : 38 per cent.; (Simpson) : 32 per cent.

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[21] Pr. Amer. Philos. Soc., 57, '18, p. 550 ff.

Unio striatissimus Anthony, '65 (Tennessee).
Dia. 30 per cent.

Unio planior Lea, '68 (Tennessee; Holston R., Washington Co., Va.).—*Pleurobema planius* Simpson, '14, p. 302.
Dia. (Lea) : 35 per cent.; (Simpson) : 33 per cent.

Unio brevis Lea, '72 (Conasauga Cr., Monroe Co., Tenn.).—*Pleurobema breve* Simpson, '14, p. 800.
Dia. (Lea) : 35 per cent.; (Simpson) : 36 per cent.

Unio swordianus Wright, '97 (Powell R., Lee Co., Va.).—*Pleurobema sword.* Simpson, '14, p. 757.

Dia. (Simpson) : 40 per cent. These measurements are taken from an extremely obese specimen. Other specimens in the original lot all fall below 40 per cent.

3. PLEUROBEMA OVIFORME HOLSTONENSE (Lea).—Dia. 50 per cent. or over.

Unio holstonensis Lea, '40 (Holston R.).—*Pleurobema holst.* Simpson, '14, p. 739.
Dia. (Lea) : 54 per cent.; Simpson) : 50, 56, 58 per cent.

Unio mundus Lea, '57 (Tennessee R., Ala.).—Synonym to *holstonense,* according to Simpson.
Dia. (Lea) : 64 per cent.

Unio tesserulæ Lea, '61 (Nolichucky R., Tenn.).—*Pleurobema tess.* Simpson, '14, p. 749.
Dia. (Lea and Simpson) : 64 per cent.

Unio pattinoides Lea, '71 (Clinch and Holston).—Synonym to *holstonense,* according to Simpson.
Dia. (Lea) : 51 per cent.

Unio acuens Lea, '71 (Tennessee R., Concord, Tenn.).—*Pleurobema acuens* Simpson, '14, p. 746.

Dia. (Lea) : 55 per cent. Simpson's measurements give 48 per cent., and thus belong to typical *oviforme.*

Unio lawi Lea, '71 (Tennessee R., Tuscumbia, Ala., Holston R.).—Synonym to *holstonense,* according to Simpson.
Dia. (Lea) : 56 per cent.

Unio bellulus Lea, '72 (Holston R.; Tennessee R., Mussel Shoals, Ala.).—Synonym to *holstonense,* according to Simpson.
Dia. (Lea) : 64 per cent.

Table of the Forms of the Oviforme-Group.

Loc.	No.	Max.	Min.	Av.	
Tennessee River.					
Florence	1	55	55	55	*holst.*
Rathburn	2	57	56	56.5	*holst.*
Chota Shoals	2	54	54	54	*holst.*
Little River Shoals	2	51	46	48.5	*ovif.* (*holst.*)
Holston River.					
Mascot	2	51	48	49.5	*ovif.* (*holst.*)
Hodges	6	48	44	46	*ovif.*
Turley Mill	1	41	41	41	*ovif.*
Noeton	1	47	47	47	*ovif.*
Holston Station	1	44	44	44	*ovif.*
South Fork Holston River.					
Pactolus	3	46	38	42	*ovif.* (*argent.*)
Bluff City	6	38	35	37	*argent.*
Emmett	10	43	32	36	*argent.* (*ovif.*)
Barron	1	38	38	38	*argent.*
Middle Fork Holston River.					
Chilhowie	8	38	31	35	*argent.*

Watauga River (just below, at Pactolus, there is *oviforme* (*argenteum,* av. 42 per cent.).

Loc.	No.	Max.	Min.	Av.	
Watauga	8	39	33	36	*argent.*

North Fork Holston River (at Holson Station is *oviforme,* 44 per cent.).

Loc.	No.	Max.	Min.	Av.	
Rotherwood	10	46	29	38	*argent.* (*ovif.*)
Hilton	8	44	32	38	*argent.* (*ovif.*)
Mendota	10	45	34	39	*argent.* (*ovif.*)
Saltville	10	38	32	35	*argent.*

Big Mocasin Creek (above Rotherwood).

Loc.	No.	Max.	Min.	Av.	
Mocassin Gap	12	39	33	35	*argent.*
Willow Springs	5	39	30	34	*argent.*
Clinch River.					
Edgemoor	1	53	53	53	*holst.*
Clinton	2	45	44	44.5	*ovif.*
Kyle Ford	3	47	38	42	*ovif.* (*argent.*)
Speers Ferry	2	38	36	37	*argent.*
Clinchport	5	47	42	44	*ovif.*
St. Paul	4	38	35	37	*argent.*
Fink	2	39	34	37	*argent.*
Cleveland	10	47	36	40	*ovif.* (*argent.*)
Raven	5	43	36	39	*argent.* (*ovif.*)
Richland	8	41	34	36	*argent.* (*ovif.*)
Cedar Bluff	12	43	33	37	*argent.* (*ovif.*)

There are some irregularities in the Clinch, which may be explained by insufficient matrial. The form *oviforme* goes up to the uppermost locality, but it becomes rare in the headwaters; and further, it may give way entirely to *argenteum* above Cedar Bluff. The decease of obesity is noted chiefly in the minima.

In *Powell River, oviforme* alone or associated with *argenteum* goes up to Olinger. However, at Big Stone Gap, among 9 specimens, the max. was 38 per cent., the min. 31 per cent., and the av. 35 per cent.: pure *argenteum.*

The same law is observed in other tributaries of the Tennessee system in East Tennessee. In *French Broad River* at Boyd Creek, *oviforme* prevails, with occasional *holstonense.* In the mountains at Asheville, the average diameter was found to be 44 per cent. (*oviforme*), with occasional *argenteum* among them. I have examined 6 specimens in the Walker collection, labeled *ravenelianum,* with the max. of 49 per cent. and the min. of 38 per cent. A very similar form I collected in *Hiwassee River* at Austral; in 8 specimens the max. was 52 per cent., the min. 43 per cent., and the av. 48 per cent.: these represent *oviforme* with occasional *holstonense.*

Also in northern Alabama and the adjoining parts of Tennessee I have found evidence for our law, as is shown by the following instances.

Loc.	No.	Max.	Min.	Av.	
Paint Rock River.					
Paint Rock	2	55	50	52.5	*holst.*
Trenton	2	41	41	41	*ovif.*
Princeton	5	47	39	42	*ovif.* (*argent.*)
Elk River.					
Fayetteville	1	44	44	44	*ovif.*
Estill Springs	8	41	33	36	*argent.* (*ovif.*)
Boiling River, Cowan	4	42	36	38	*argent.* (*ovif.*)

The last two localities are about equivalent as to their situation.

Group of Pleurobema clava.

Pleurobema clava is absent in the upper Tennessee-region. It turns up, however, in the Tennessee drainage in northern Alabama. Yet my material is too scanty to form an opinion as to the interrelation of this form with *oviforme. Pl. clava* is abundant in the upper

Ohio system, and on account of its close affinity to *Pl. oviforme,* we might expect to find our law expressed. But the fact is that in this region no large-river-type is present, *Pl. clava* avoiding larger streams. Measurements of the material at hand have furnished no evidence for a change of obesity correlated with station. The measurements correspond roughly to those of the typical *oviforme* (between 40 and 50 per cent.), and there is also no form parallel to *argenteum.*

I also have investigated material from the Coosa River in Georgia and Alabama belonging to *Pleurobema decisum* (Lea) and *Pl. chattanoogaënse* (Lea). These two species undoubtedly represent the *clava*-group and the typical *oviforme.* Very slight evidence was found of a change of obesity according to station, yet some indications of it were present. The lowest figures for the average diameter were obtained in specimens from *Conasauga River* in Whitfield Co., Ga.; the highest figures in the lower reaches of *Coosa River* in Chilton and Elmore Cos., Ala. Yet the differences are slight at the best (max. 55, min. 38 per cent.), and the irregularities are many. Also the material is very unequal as regards the number of specimens measured from one and the same locality. Thus I pass over these forms, only calling attention to the posibility that the existence of the same law might be demonstrated also in these cases.

DROMUS DROMAS (Lea) and DR. DROMAS CAPERATUS (Lea).

Simpson, '14, pp. 341, 343.

Wilson and Clark ('14, pp. 54, 63) have first pointed out that, in the Cumberland River, these two forms run together, and that the flattened *caperatus* is in the headwaters, and the swollen *dromas* in the main river (see also Ortmann, '18, p. 566).

In this species, conditions are somewhat complicated by the fact that the swollen form has also a peculiar "hump," or large tubercle, upon each valve, which becomes more or less obliterated in the flat form, being often entirely missing. Thus it is rather hard to draw a line. We may assume, that *D. dromas* is the swollen type, with the diameter of 50 per cent. or over, and a well-developed hump;

while *D. dromas caperatus* is the compressed form, with the diameter less than 50 per cent., and without hump. But we must bear in mind that some moderately swollen individuals have no hump; and that, more frequently, flat specimens may have more or less distinct traces of this hump.

The original measurements taken from Lea, Conrad, and Simpson, give for the *typical* form a diameter ranging from 50 to 84 per cent., while the diameter of *caperatus* ranges from 42 to 48 per cent.

I am able to submit the following table.

Loc.	No.	Max.	Min.	Av.	
Tennessee River.					
Tuscumbia	4	74	59	66	*drom.*
Konxville	1	58	58	58	*drom.*
Holston River.					
McMillan	2	56	53	54.5	*drom.*
Mascot	10	61	43	52	*drom.* (*cap.*)
Hodges	3	58	50	55	*drom.*
Turley Mill	3	63	52	56	*drom.*
Noeton	1	48	48	48	*cap.*
Holston Station	3	56	47	52	*drom.* (*cap.*)

Farther up in the Holston, this species has not been found. It is clear that the form *caperatus* is not well developed here, and this is also shown by the fact that traces of the hump are found to the uppermost station, although, on the other hand, already one of the specimens at McMillan is without any hump. In the *Clinch* and *Powell,* conditions are more favorable to the development of the *caperatus*-type, as is seen in the next table.

Loc.	No.	Max.	Min.	Av.	
Clinch River.					
Solway	2	53	49	51	*drom.* (*cap.*)
Edgemoor	16	58	41	49	*cap.* (*drom.*)
Clinton	6	52	43	47	*cap.* (*drom.*)
Offutt	5	51	40	46	*cap.* (*drom.*)
Clinch River Station	1	46	46	46	*cap.*
Powell River.					
Combs	1	46	46	46	*cap.*
Arthur	1	42	42	42	*cap.*

Combs is about equivalent to Clinch River Station. Also here the development of the hump is variable, but specimens without it prevail at the upper stations. The metropolis of *caperatus* is clearly in Clinch and Powell Rivers, toward the headwaters. It should be noticed that this species does not go very far up in the rivers, and that it is by no means a small-creek-form.

GROUP OF OBOVARIA SUBROTUNDA IN THE UPPER OHIO-DRAINAGE.

The synonymy of these forms is as follows (see Ortmann, '18, p. 567, 568, but the name *lens* has been restored for *levigata*).

1. OBOVARIA SUBROTUNDA (Rafinesque).—Dia. 60 per cent. or over.

Obliquaria subrotunda Rafinesque, '20 (Ohio).—*Obovaria subrotunda* Vanatta, '15, p. 552.

Dia. (Vanatta) : 72 per cent.

Unio circulus Lea, '29 (Ohio R., Cincinnati; Monongahela R., Pittsburgh).—*Obovaria circ.* Simpson, '14, p. 291.

Dia. (Lea) : 73 per cent.; (Simpson) : 58, 67, 72 per cent. (the first given by Simpson falls under the variety!).

2. *Obovaria subrotunda lens* (Lea).—Dia. less than 60 per cent.

Unio lens Lea, '31 (Ohio and Tennessee).—*Obovaria lens* Simpson, '14, p. 293.

Dia. (Lea) : 48 per cent.; (Simpson) : 52 per cent.

The material from the *upper Ohio system* shows that these two forms intergrade completely, as I have pointed out already in 1909, and *subrotunda* is the large-river-form, while *lens* is found toward the headwaters.

Loc.	No.	Max.	Min.	Av.	
Ohio River.					
Portland	12	66	53	62	*subr.* (*lens*)
Parkersburg	2	62	59	60.5	*subr.* (*lens*)
St. Mary's	7	67	51	62	*subr.* (*lens*)
Coraopolis	5	64	57	61	*subr.* (*lens*)
Monongahela River.					
Charleroi	5	68	53	60	*subr.* (*lens*)
West Fork River.					
Lynch Mines	4	56	50	53	*lens*
Lightburn	3	49	48	49	*lens*
Weston	2	49	45	47	*lens*

Allegheny River.					
Natrona	1	52	52	52	*lens*
Godfrey	1	51	51	51	*lens*
Crooked Creek.					
Rosston	12	59	48	52	*lens*
Creekside	5	51	48	50	*lens*

The sudden decrease of obesity from the Monongahela to West Fork River is clearly due to the absence of material from a long stretch in the Monongahela. Also in the Allegheny the change is rather abrupt, due to scarcity of material. The gradual transition of the two forms is, however, quite evident in the *Beaver-drainage.*

Loc.	No.	Max.	Min.	Av.	
Beaver River.					
Wampum	14	64	49	53	*lens* (*subr.*)
Shenango River.					
Harbor Bridge	3	56	50	53	*lens*
Pulaski	2	58	49	53.5	*lens*
Clarksville	7	54	48	51	*lens*

Also in *Elk River* in West Virginia this is seen.

Loc.	No.	Max.	Min.	Av.	
Elk River.					
Shelton	1	67	67	67	*subr.*
Clay	2	62	60	61	*subr.*
Gassaway	7	70	56	61	*subr.* (*lens*)
Sutton	9	65	53	58	*lens* (*subr.*)

Some material from the *Little Kanawha* also fits into the scheme, but it should be pointed out that the locality on Hughes River, although not quite so far upstream as the others, surely is in the smaller stream.

Loc.	No.	Max.	Min.	Av.	
Little Kanawha River.					
Grantsville	2	68	59	63.5	*subr.* (*lens*)
Burnsville	5	59	50	53	*lens*
North Fork Hughes River.					
Cornwallis	1	50	50	50	*lens*

GROUP OF OBOVARIA SUBROTUNDA IN THE UPPER TENNESSEE.

In the uppermost Tennessee drainage, *Obovaria subrotunda* is extremely rare; above Knoxville, it does not go anywhere into the smaller streams, and I have only a few specimens from the lower Clinch and the lower Holston. These shells are *O. subrotunda,* associated with *lens* of moderate obesity (max. 62 per cent., min. 55 per cent.).

In a tributary of the Tennessee in Alabama, the law again becomes visible. Material from *Paint Rock River* has been examined: although only the form *lens* is represented, it shows distinctly a decrease of the obesity in the upstream direction, and at the lowermost station specimens are found which are very close to *subrotunda.*

Loc.	No.	Max.	Min.	Av.	
Paint Rock River.					
Paint Rock	14	59	46	54	*lens*
Trenton	12	53	46	49.6	*lens*
Holly Tree	1	48	48	48	*lens*
Princeton	12	52	43	49.3	*lens*

The irregularity at Holly Tree, of course, is due to scarcity of material.

These are the instances I am able to offer, at the present time, for the phenomenon that a species changes its obesity along the course of a river or rivers. I am quite sure that, in the upper Ohio and upper Tennessee drainages, there are hardly any other instances of this kind, for I am very familiar with these faunas. There is only one additional species both in the Ohio and Tennessee drainages, *Lampsilis ovata* (Say), which develops a variety, *L. ovata ventricosa* (Barnes), which prevails towards the headwaters, and is exclusively found in certain smaller creeks. These forms, however, do not so much differ in obesity, but in other characters (development of posterior ridge and truncation of posterior slope).

Also possibly some species of *Truncilla* might show the same changes in obesity (*Truncilla torulosa* (Raf.), turning, in the upper Ohio into *Tr. rangiana* (Lea), and in the upper Tennessee into *Tr. gubernaculum* (Reeve)). But these require further study.

I have no doubt that in other river-systems other species or groups may be found which are governed by the same law. But, on the other hand, *there are surely other forms which positively do not follow it,* and exhibit the same obesity all along the course of a river in which they are found.

This can be tested, of course, only in such forms which have a wide distribution, and are found both in large and small rivers. I have measured a number of such, but did not find any evidence for our law in the following cases.

Elliptio dilatatus (Raf.).—Distribution tremendous, equally abundant in large rivers and small streams: but no trace of the law observed.

Strophitus edentulus (Say).—The same wide distribution in all kinds of streams, but no evidence of the law.

(It should be noted that no species belonging to the subfamily *Anodontinas* has shown, so far, any evidence of submitting to this law.)

Ptychobranchus fasciolare (Raf.).—The same holds good for this species as for the two preceding ones.

Actinonaias carinata (Barn.) (= *Nephronaias ligamentina*).—Although not going into the smallest headwaters, this species is found in smaller and larger rivers, but no change of obesity is observed.

Eurynia recta latissima (Raf.).—Has a very wide distribution from the large rivers well up into the headwaters, but is remarkably uniform in obesity.

Lampsilis siliquoidea (Barn.) (= *luteola*).—Practically ubiquitous in the interior drainage (although missing in the upper Tennessee). No relation observed between size of stream and obesity, although the shell is very variable.

Lampsilis fasciola Raf. (= *multiradiata*).—Practically everywhere in the interior drainage, but obesity not responding to station.

Truncilla triquetra Raf.—Of wide distribution, and in streams of various size, but without marked change in obesity.

Truncilla capsæformis (Lea).—Widely distributed and common in the upper Tennessee region, found in small creeks and large rivers, but uniform in the convexity of the valves.

In addition it should be remarked that in none of the species belonging to the Atlantic drainage this law has been observed to exist. This is most evident in the common *Elliptio complanatus* (Dillw.). This is found practically everywhere, in large rivers as well as in small streams, and varies greatly in obesity. But no correlation between the diameter of the shell and the size of the stream has been discovered.

In the tables given above, one character has been brought out preëminently, that is *obesity,* or diameter of the shell as related to length.

But, in addition, another fact has been discovered, which is the following. *A shell which decreases in diameter in the headwaters, makes up, so to speak, for the loss by a gain in size, that is to say, in circumference, and this is best expressed by the total length of the shell.* The latter not having been given in the tables, I supplement this here for the several species discussed.

The following *maxima of length* have been observed (the large river form is given first; the headwaters form in the second place).

Fusconaia subrotunda: 107 mm.; *F. subr. kirtlandiana:* 133 mm.

Fusconaia pilaris: 70 mm.; *F. pil. lesueuriana:* 84 mm.; *F. pil. bursa-pastoris:* 100 mm. (Simpson gives even 110 mm. for the last one).

Fusconaia flava trigona: 67 mm.; *F. flava:* 90 mm. (This is not everywhere so striking, for locally the typical *flava* appears as a dwarfed race, as for instance in Crooked Creek in Pa., where the largest specimen is only 74 mm. long, but longer yet than the largest *trigona.*)

Fusconaia cuneolus appressa: 63 mm.; *F. cuneolus:* 68 mm.

Fusconaia edgariana: 63 mm.; *F. edg. analoga:* 70 mm.

Fusconaia barnesiana tumescens: 67 mm.; *F. barnesiana:* 77 mm.; *F. barn. bigbyensis:* 86 mm.

Lexingtonia dolabelloides: 56 mm.; *L. dol. conradi:* 68 mm.

Pleurobema oviforme holstonense: 58 mm.; *P. oviforme:* 68 mm.; *P. ovif. argenteum:* 96 mm.

Obovaria subrotunda: 59 mm.; *O. subr. lens:* 67 mm.

Only in *Pleurobema cordatum catillus* and *P. cord. coccineum* this phenomenon is not evident, and it could not be established in the case of *Dromus dromas* and *caperatus.* For the others, as may be seen by the above figures, it stands out as a striking fact, and cannot be due, by any means, to accident. Thus we must accept it as demonstrated, *that in most shells which show a decrease in diameter in the upstream direction, this decrease is compensated, to a degree, by the greater size of the shell as expressed by its length.*

Further, we have seen in certain forms (*Quadrula metanevra* and *Qu. cylindrica, Dromus dromas*), that a peculiar kind of surface sculpture, namely large knobs and tubercles, tend to disappear in the headwaters. This is also connected, more or less distinctly, with a flattening of the shell. It would be interesting to discover additional cases of this kind, and may be found in *Truncilla torulosa* and *gubernaculum* of the upper Tennessee. But it surely is not a general law, since there are other shells, which show no change in sculpture along the course of a river, and since there are other instances, where the opposite seems to be the case. The group of *Amblema plicata* seems to belong here, where a strongly sculptured and flat form (*A. costata*) belongs to the headwaters, while a smoother and more swollen form (*peruviana*) is in the largest rivers.[22]

In this connection it should be pointed out, that a similar case is known in the freshwater Gastropod *Io*. The facts have been positively established by C. C. Adams[23]; a tuberculated or spinose form (*Io spinosa* Lea) is found in the larger streams; a smooth form (*Io fluvialis* Say) in the headwaters. The present writer is able to confirm this by his own observations. The smoothness of the specimens of *Io* in the upper Powell, Clinch, and Holston in Virginia is very striking; tuberculate individuals begin to appear farther down, and real spiny ones not till the state line of Tennessee is reached. The transition is quite gradual.

CONCLUSIONS.

Certain Naiades change their shape along the course of one and the same river in such a way, that

1. the more obese (swollen) form is found farther down in the

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[22] See Wilson and Clark, '14, p. 63; Utterback, '16, p. 41.

[23] *Mem. Nat. Acad. Sci.,* 12, 1915.

large rivers, and passes gradually, in the upstream direction, into a less obese (compressed) form in the headwaters;

2. with the decrease in obesity often an increase in size (length) is correlated;

3. a few shells which have, in the larger rivers, a peculiar sculpture of large tubercles, lose these tubercles in the headwaters.

The question arises: *what is the meaning of these changes in shape?* No positive conclusion is as yet possible, chiefly for two reasons: first, that there are only some species (and comparatively few), in which this law is observed, while others positively do not show it; and in the second place, that, although the size of the stream undoubtedly is connected with this phenomenon, we do not know, whether *size alone is the essential factor,* or whether additional factors belonging to those constituting the small-stream-community are responsible.

A few points, however, should be mentioned, which might finally lead to or help in the proper understanding of the facts.

1. Practically all of the shells which show this phenomenon are of a rather primitive structure. The genera *Fusconaia, Amblema, Quadrula, Lexingtonia,* and *Pleurobema,* belong to the most primitive types of North American Naiades; and *Dromus* and *Obovaria* are comparatively primitive among the subfamily *Lampsilinæ.* No Naiades which stand on a high stage of differentiation have given any distinct evidence for our law.

2. It must not be forgotten that dispersal of almost all our Naiades is accomplished in the larval stage, when the larvæ live parasitic upon fishes, and that certain species of shells are restricted to certain species of fishes as hosts. Thus the distribution of the fish-host, and the ecological peculiarities of it, must largely influence the distribution of the Naiades. Since we have fishes which are migratory, while others are more stationary, it might be that Naiades living parasitic upon the latter kind have a smaller chance to be carried far away from their native grounds, while others, parasitic upon migratory fishes, are promiscuously scattered over the whole river-system, being often deposited far from their place of birth. In the first case, development of local races, in

consequence of reaction to local environmental conditions, is favored; in the second case, no such local development is possible, any tendency toward it being promptly obliterated by the mixing of the different stocks.

This, however, requires additional investigation. In most of the species, chiefly those from the upper Tennessee region, we do not possess sufficient information as to the fish host and its ecological habits. My chief purpose in the present paper was, to bring out the evidence for the actual existence of the law.